PHILOSOPHICAL

TRANSACTIONS.

I. *Account of the Diſcovery of a Sixth and Seventh Satellite of the Planet Saturn; with Remarks on the Conſtruction of its Ring, its Atmoſphere, its Rotation on an Axis, and its ſpheroidical Figure.* *By* William Herſchel, *LL.D. F. R. S.*

Read November 12, 1789.

IN a ſhort Poſtſcript, added to my laſt Paper on Nebulæ, I announced the diſcovery of a *ſixth ſatellite* of Saturn, and mentioned, that I intended to communicate the particulars of its orbit and ſituation to the Members of the Royal Society, at their next meeting. I have now the honour to preſent them, at the ſame time, with an account of two ſatellites inſtead of one; and have called them the *ſixth* and *ſeventh*, though their ſituation

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ſituation in the Saturnian ſyſtem intitles them, very probably, to the firſt and ſecond place. This I have done to the end that in future we may not be liable to miſtake, in referring to former obſervations or tables, where the five known ſatellites have been named according to the order they have hitherto been ſuppoſed to hold in the range of diſtance from the planet.

It may appear remarkable, that theſe ſatellites ſhould have remained ſo long unknown to us, when, for a century and an half paſt, the planet to which they belong has been the object of almoſt every aſtronomer's curioſity, on account of the ſingular phænomena of its ring. But it will be ſeen preſently, from the ſituation and ſize of the ſatellites, that we could hardly expect to diſcover them till a teleſcope of the dimenſions and aperture of my forty-feet reflector ſhould be conſtructed; and I need not obſerve how much we Members of this Society muſt feel ourſelves obliged to our Royal Patron, for his encouragement of the ſciences, when we perceive that the diſcovery of theſe ſatellites is intirely owing to the liberal ſupport whereby our moſt benevolent King has enabled his humble aſtronomer to complete the arduous undertaking of conſtructing this inſtrument.

The planet Saturn is, perhaps, one of the moſt engaging objects that aſtronomy offers to our view. As ſuch it drew my attention ſo early as the year 1774; when, on the 17th of March, with a 5½-feet reflector, I ſaw its ring reduced to a very minute line, as repreſented in fig. 1. (Tab. I.) On the 3d of April, in the ſame year, I found the planet as it were ſtripped of its noble ornament, and dreſſed in the plain ſimplicity of Mars. See fig. 2. I paſs over the following year, in which, with a 7-feet reflector, I ſaw the ring gradually open, till it came to the appearance expreſſed in fig. 3. (Tab. II.) the original of which was delineated from nature, on the 20th of June, 1788, by means of a very good 10-feet reflector.

It ſhould be noticed, that the black diſk, or belt, upon the ring of Saturn is not in the middle of its breadth; nor is the ring ſubdivided by many ſuch lines, as has been repreſented in divers treatiſes of aſtronomy; but that there is one ſingle, dark, conſiderably broad line, belt, or zone, upon the ring, which I have always permanently found in the place where my figure repreſents it. I give this, however, only as a view of the northern plane of the ring, as the ſituation of the planet has hitherto not afforded me any other. The ſouthern one, which is lately come to be expoſed to the ſun, will ſhortly be opened ſufficiently to enable me to give alſo the ſituation of its belts, if it ſhould have any.

From my obſervations it appears, that the zone on the northern plane of the ring is not, like the belts of Jupiter or thoſe of Saturn, ſubject to variations of colour and figure; but is moſt probably owing to ſome permanent conſtruction of the ſurface of the ring itſelf. That however, for inſtance, this black belt cannot be the ſhadow of a chain of mountains, may be gathered from its being viſible all round on the ring; for at the ends of the anſæ there could be no ſhades viſible, on account of the direction of the ſun's illumination, which would be in the line of the chain; and the ſame argument will hold good againſt ſuppoſed caverns or concavities. It is moreover pretty evident, that this dark zone is contained between two concentric circles, as all the phænomena anſwer to the projection of ſuch a zone. Thus, in fig. 4. which was taken the 11th of May, 1780, we may ſee, that the zone is continued all round the ring, with a gradual decreaſe of breadth towards the middle, anſwering to the appearance of a narrow circular plane, projected into an ellipſis.

As to the ſurmiſe, which might occur to us, of a diviſion of the ring, or rather of two rings, one about the other, with a diſtance of open ſpace between them, it does not appear eligible to venture on ſo artificial a conſtruction, by way of explaining a phænomenon that does not abſolutely demand it. If one ring, of a breadth ſo conſiderable as that of Saturn, is juſtly to be eſteemed the moſt wonderful arch that, by the laws of gravity, can be held together, how improbable muſt it appear to ſuppoſe it ſubdivided into narrow ſlips of rings, which by this ſeparation will be deprived of a ſufficient depth, and thus loſe the only dimenſion which can keep them from falling upon the planet? It is however true, that as yet we do not know of the rotation of the ring, which may be of ſuch a proper velocity as greatly to aſſiſt its ſtrength; and that, in the ſubdiviſions, of courſe the different velocities for each diviſion may be equally ſuppoſed to keep them up. If the ſouthern plane ſhould prove to be very differently marked, it will at once remove every ſurmiſe of ſuch a diviſion; but if it ſhould offer us the ſame appearance of a dark zone, in the ſame ſituation, and of an equal breadth with the one I have obſerved on the northern ſide, I would ſtill remark, that, ſince a moſt effectual way to verify the duplicity of the ring is within our reach, it will be the beſt way to ſuſpend our judgement till that can be put to the trial. The method I allude to is an occultation of ſome conſiderable ſtar by Saturn, when, if the ring be divided, it will be ſeen between the openings, as well as between the ring and Saturn.

With regard to the nature of the ring, we may certainly affirm, that it is no leſs ſolid and ſubſtantial than the planet itſelf. The ſame reaſons which prove to us the ſolidity of the one will be full as valid when applied to the other. Thus we ſee, in fig. 3. and 4. the ſhadow of the body of Saturn upon the ring, which, in fig. 3. is eclipſed towards the north, on the following ſide, and in fig. 4. about the middle, according to the oppoſite ſituation of the ſun. In the ſame manner we ſee the ſhadow of the ring caſt on the planet, where in fig. 1. and 2. we find it on the equatorial part; and May 28, 1780, I ſaw it towards the ſouth. If we deduce the quantity of matter, contained in the body, from the power whereby the ſatellites are kept in their orbits, and the time of their revolution, it muſt be remembered, that the ring is included in the reſult. It is alſo in a very particular manner evident, that the ring exerts a conſiderable force upon theſe revolving bodies, ſince we find them ſtrongly affected with many irregularities in their motions, which we cannot properly aſcribe to any other cauſe than the quantity of matter contained in the ring; at leaſt we ought to allow it a proper ſhare in the effect, as we do not deny but that the conſiderable equatorial elevation of Saturn, which I ſhall eſtabliſh hereafter, muſt alſo join in it.

The light of the ring of Saturn is generally brighter than that of the planet: for inſtance, April 19, 1777, I ſaw the ſouthern part of the ring, which paſſed before the body, very plainly brighter than the diſk of Saturn, on which it was projected; and on the 27th of the ſame month, I found, that with a power of 410, my ſeven-feet reflector had hardly light enough for Saturn, when the ring was notwithſtanding ſufficiently bright. Again, the 11th of March, 1780, I tried the powers of 222, 332, and 449, ſucceſſively, and found the light of Saturn leſs intenſe than that of the ring; the colour of the body with the high powers turning to a kind of yellow, while that of the ring ſtill remained white. The ſame reſult happened on June 25, 1781, with the power 460.

I come now to one of the moſt remarkable properties in the conſtruction of the ring, which is its extreme thinneſs. The ſituation of Saturn, for ſome months paſt, has been particularly favourable for an inveſtigation of this circumſtance; and my experiments have been ſo complete, that there can remain no doubt on this head.

When we were nearly in the plane of the ring, I have repeatedly ſeen the firſt, the ſecond, and the third ſatellites, nay even the ſixth and ſeventh, paſs before and behind the ring in ſuch a manner that they ſerved as excellent micrometers to eſtimate its thickneſs by. It may be proper to mention a few inſtances, eſpecially as they will ſerve to ſolve ſome phænomena that have been remarked by other aſtronomers, without having been accounted for in any manner that could be admitted, conſiſtently with other known facts. July 18, 1789, at 19 h. 41′ 9″, ſidereal time, the firſt ſatellite ſeemed to hang upon the following arm, declining a little towards the north, and I ſaw it gradually advance upon it towards the body of Saturn; but the ring was not ſo thick as the lucid point. July 23, at 19 h. 41′ 8″, the ſecond ſatellite was a very little preceding the ring; but the ring appeared to be leſs than half the thickneſs of the ſatellite. July 27, at 20 h. 15′ 12″, the ſecond ſatellite was about the middle, upon the following arm of the ring, and towards the ſouth; and the ſixth ſatellite on the farther end, towards the north; but the arm was thinner than either of them. Auguſt 29, at 22 h. 12′ 25″, the third ſatellite was upon the ring, near the end of the preceding arm; and my remark at the time when I ſaw it was, that the arm ſeemed not to be the fourth, at leaſt not the third, part of the diameter of the ſatellite, which, in the ſituation it was, I took to be leſs than one ſingle ſecond in diameter. At the ſame time I alſo ſaw the ſeventh ſatellite, at a little diſtance following the third, in the ſhape of a bead upon a thread, projecting on both ſides of the ſame arm: hence we are ſure, that the arm alſo appeared thinner than the ſeventh ſatellite, which is conſiderably ſmaller than the ſixth, which again is a little leſs than the firſt ſatellite. Auguſt 31, at 20 h. 48′ 26″, the preceding arm was loaded about the middle by the third ſatellite. October 15, at 0 h. 43′ 44″, I ſaw the ſixth ſatellite, without obſtruction, about the middle of the preceding arm, though the ring was but barely viſible with my forty-feet reflector, even while the planet was in the meridian; however, we were then a little inclined to the plane of the ring, and the third ſatellite, when it came near its conjunction with the firſt, was ſo ſituated that it muſt have partly covered the firſt a few minutes after the time I loſt it behind my houſe. In all theſe obſervations the ring did not in the leaſt interfere with my view of the ſatellites. October 16, I followed the ſixth and ſeventh ſatellites up to the very diſk of the planet; and the ring, which was extremely faint, oppoſed no manner of obſtruction to my ſeeing them gradually approach the diſk, where the ſeventh vaniſhed at 21 h. 46′ 44″, and the ſixth at 22 h. 36′ 44″.

I might bring many other inſtances, if the above were not quite ſufficient for the purpoſe. There is, however, ſome conſiderable ſuſpicion, that, by a refraction through ſome very rare atmoſphere on the two planes of the ring, the ſatellites might be lifted up and depreſſed, ſo as to become viſible on both ſides of the ring, even though the ring ſhould be equal in thickneſs to the diameter of the ſmalleſt ſatellite, which may amount to a thouſand miles. As for the argument of its incredible thinneſs, which ſome aſtronomers have brought from the ſhort time of its being inviſible, when the earth paſſes through its plane, we cannot ſet much value upon them; for they muſt have ſuppoſed the edge of the ring, as they have alſo repreſented it in their figures, to be ſquare; but there is the greateſt reaſon to ſuppoſe it either ſpherical or ſpheroidical, in which caſe evidently the ring cannot diſappear for any long time. Nay, I may venture to ſay, that the ring cannot poſſibly diſappear on account of its thinneſs; ſince, either from the edge or the ſides, even if it were ſquare on the corners, it muſt always expoſe to our ſight ſome part which is illuminated by the rays of the ſun: and that this is plainly the caſe, we may conclude from its being viſible in my teleſcopes during the time when others of leſs light had loſt it, and when evidently we were turned towards the unenlightened ſide, ſo that we muſt either ſee the rounding part of the enlightened edge, or elſe the reflection of the light of Saturn upon the ſide of the darkened ring, as we ſee the reflected light of the earth on the dark part of the new moon. I will, however, not decide which of the two may be the caſe; eſpecially as there are other very ſtrong reaſons to induce us to think, that the edge of the ring is of ſuch a nature as not to reflect much light.

I cannot leave this ſubject without mentioning both my own former ſurmiſes, and thoſe of ſeveral other aſtronomers, of a ſuppoſed roughneſs in the ſurface of the ring, or inequality in the planes and inclinations of its flat ſides. They aroſe from ſeeing luminous parts on its extent, which were ſuppoſed to be projecting points, like the moon's mountains; or from ſeeing one arm brighter or longer than another; or even from ſeeing one arm when the other was inviſible. I was, in the beginning of this ſeaſon, inclined to the ſame opinion, till one of theſe ſuppoſed luminous points was kind enough to venture off the edge of the ring, and appeared in the ſhape of a ſatellite. Now, as I had collected every inequality of this ſort, it was eaſy enough for me afterwards to calculate all ſuch ſurmiſes by the known periodical time of the firſt, ſecond, third, ſixth, and ſeventh ſatellites; and I have always found that ſuch appearances were owing to ſome of theſe ſatellites which were either before or behind the ring. The 20th of October, for inſtance, at 22h. 35′ 46″, I ſaw four of Saturn's ſatellites all in one row, and at almoſt an eqnal diſtance from each other, on the following ſide; and yet the firſt ſatellite, which was the fartheſt of them all, was only about half-way towards its greateſt elongation from the body of Saturn, as may be ſeen in fig. 5. (Tab. III.). How eaſily, with an inferior teleſcope, this might have been taken for one of the arms of Saturn, I leave thoſe to gueſs who know what a degree of accuracy it muſt require to diſtinguiſh objects that are ſo minute, and at the ſame time ſo faint, on account of their nearneſs to the diſk of the planet. Upon the whole, therefore, I cannot ſay, that I had any one inſtance that could induce me to believe the ring was not of an uniform thickneſs; that is, equally thick at equal diſtances from the center, and of an equal diameter throughout the whole of its conſtruction. The idea of protuberant points upon the ring of Saturn, indeed, is of itſelf ſufficient to render the opinion of their exiſtence inadmiſſible, when we conſider the enormous ſize ſuch points ought to be of, for us to ſee them at the diſtance we are from the planet.

From theſe ſuppoſed luminous points I am, by imperceptible ſteps, brought to the diſcovery of two ſatellites of Saturn, which had eſcaped unnoticed, on account of their little diſtance from the planet, and faintneſs; which latter is partly to be aſcribed to their ſmallneſs, and partly to being ſo near the light of the ring and diſk of Saturn. Strong ſuſpicions of the exiſtence of a ſixth ſatellite I have long entertained; and, if I had been more at leiſure two years ago, when the diſcovery of the two Georgian ſatellites took me as it were off the ſcent, I ſhould certainly have been able to announce its exiſtence as early as the 19th of Auguſt, 1787, when, at 22 h. 18′ 56″, I ſaw, and marked it down as being probably, a ſixth ſatellite, which was then about 12 degrees paſt its greateſt preceding elongation. But, as I obſerved before, not having time to give my thoughts to the ſubject, I reſerved a full inveſtigation of the number of ſatellites, and the nature of the ring of Saturn for a future opportunity. Beſides, not having any tables of the ſatellites, I could not confidently ſay, whether the fifth ſatellite was not one of the five which I perceived in motion that night, though afterwards I found, that the real fifth had alſo been in view, and was marked down as a ſtar, by the letter *b*, in a figure I delineated of Saturn and its ſatellites that evening.

In the year 1788 very little could be done towards a diſcovery, as my twenty-feet ſpeculum was ſo much tarniſhed by *zenith ſweeps*, in which it had been more than uſually expoſed to falling dews, that I could hardly ſee the Georgian ſatellites. In hopes of great ſucceſs with my forty-feet ſpeculum, I deferred the attack upon Saturn till that ſhould be finiſhed; and having taken an early opportunity of directing it to Saturn, the very firſt moment I ſaw the planet, which was the 28th of laſt Auguſt, I was preſented with a view of ſix of its ſatellites, in ſuch a ſituation, and ſo bright, as rendered it impoſſible to miſtake them, or not to ſee them. The retrograde motion of Saturn amounted to nearly 4½ minutes *per* day,

which

which made it very eaſy to aſcertain whether the ſtars I took to be ſatellites really were ſo; and, in about two hours and an half, I had the pleaſure of finding, that the planet had viſibly carried them all away from their places. I continued my obſervations conſtantly, whenever the weather would permit; and the great light of the forty-feet ſpeculum was now of ſo much uſe, that I alſo, on the 17th of September, detected the ſeventh ſatellite, when it was at its greateſt preceding elongation.

As ſoon as I had obſervations enough to make tables of the motion of theſe new ſatellites, I calculated their place backwards, and ſoon found that many ſuſpicions of theſe ſatellites, in the ſhape of protuberant points on the arms, were confirmed, and ſerved to correct the tables, ſo as to render them more perfect. Fig. 6. repreſents the ſeven ſatellites of Saturn, as they were ſituated October 18, at 21 h. 22′ 45″. The ſmall ſtar *s* ſerved to ſhew the motion of the planet in a ſtriking manner; as, in about 3¾ hours after the above-mentioned time, the whole Saturnian ſyſtem was completely moved away, ſo as to leave the ſtar *s* as much following the ſecond and firſt ſatellites, which then were in conjunction, as it now was before the ſecond.

By comparing together many obſervations of the ſixth ſatellite, I find, that it completes a ſidereal revolution about Saturn in one day, 8 hours, 53′ 9″. And if we ſuppoſe, with M. DE LA LANDE *, that the fourth is at the mean diſtance of 3′ from the center of Saturn, and performs one revolution in 15 d. 22 h. 34′ 38″, we find the diſtance of the ſixth, by KEPLER's law, to be 35″,058. Its light is conſiderably ſtrong, but not equal to that of the firſt ſatellite; for, on the 20th of

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* Aſtr. § 2996, 2997.

October, at 19 h. 56′ 46″, when theſe two ſatellites were placed as in fig. 7. the firſt, notwithſtanding it was nearer the planet than the ſixth, was ſtill viſibly brighter than the latter. It would, however, be worth while to try whether a good achromatic teleſcope, of a large aperture, might not poſſibly ſhew it at the time of its greateſt diſtance from the planet, and when no other ſatellite is near; that is, provided it will ſhew the other five ſatellites with great eaſe, as otherwiſe there will be no reaſon to expect it ſhould ſhew the ſixth.

In the period of this ſatellite I have employed the obſervation of the 19th of Auguſt, 1787, as, from other calculations, it ſeems the revolution is determined near enough to reach back ſo far.

The moſt diſtant obſervations of the ſeventh ſatellite, being compared together, ſhew, that it makes one ſidereal revolution in 22 hours, 40 minutes, and 46 ſeconds: and, by the ſame *data* which ſerved to aſcertain the dimenſion of the orbit of the ſixth, we have the diſtance of the ſeventh, from the center of Saturn, no more than 27″366. It is incomparably ſmaller than the ſixth; and, even in my forty-feet reflector, appears no bigger than a very ſmall lucid point. I ſee it, however, alſo very well in the twenty-feet reflector; to which the exquiſite figure of the ſpeculum not a little contributes. It muſt nevertheleſs be remembered, that a ſatellite once diſcovered is much eaſier to be ſeen than it was before we were acquainted with its place.

The revolution of this ſatellite is not nearly ſo well aſcertained as that of the former. The difficulty of having a number of obſervations is uncommonly great; for, on account of the ſmallneſs of its orbit, the ſatellite lies generally before and behind the planet and its ring, or at leaſt ſo near them that, except in very fine weather, it cannot eaſily be ſeen well enough to take its place with accuracy. On the other hand, the greateſt elongations allow ſo much latitude for miſtaking its true ſituation, that it will require a conſiderable time to divide the errors that muſt ariſe from imperfect eſtimations.

The orbits of theſe two ſatellites, as appears from many obſervations of them, are exactly in the plane of the ring, or at leaſt deviate ſo little from it, that the difference cannot be perceived. It is true, there is a poſſibility that the line of their nodes may be in, or near, the preſent greateſt elongation, in which caſe the orbits may have ſome ſmall inclination; but as I have repeatedly ſeen them run along the very minute arms of the ring, even then the deviation cannot amount to more than perhaps one or two degrees; if, on the contrary, the nodes ſhould be ſituated near the conjunction, this quantity would be ſo conſiderable that it could not have eſcaped my obſervation.

From the ring and ſatellites of Saturn we now turn our thoughts to the planet, its belts, and its figure.

April 9, 1775. I obſerved a northern belt on Saturn, which was a little inclined to the line of the ring.

May 1, 1776. There was another belt, inclined about 15 degrees to the ſame line, but it was more to the ſouth, and on the following ſide came up to the place in which the ring croſſes the body.

July 13, —— The belt was again depreſſed towards the north, almoſt touching the line where the ring paſſed behind the body.

April 8, 1777. There were two fine belts, both a little inclined to the ring.

June 20, 1778. There were two belts parallel to the ring; but the northern one had ſome faint, cloudy appearance, towards the preceding, or weſtern ſide.

May 11, 1779. Two equatorial belts.

— 13, —— A bright belt over a dark one.

— 22, —— One dark, and one very faint white belt.

— 23, —— A dark belt, and a pretty bright white one.

Jan. 21, 1780. Two belts; the moſt north clouded.

— 22, —— Faint belts.

May 17, —— A dark, equatorial belt.

— 23, —— A ſtrong, equatorial belt.

June 19, at 10 h. 15′, With a new, excellent ſeven-feet ſpeculum, I ſee two belts, and a cloudy appearance, which is not come up to the middle; but, as it is a large figure, ſome part of it is already paſt the center (this is, provided Saturn turns upon its axis the ſame way as Jupiter does). See fig. 8. where the ring is omitted.

June 20, 1780. 10 h. 10′, The ſame figure is on the diſk, but ſeems to be more central than it was yeſterday.

— 21, 9 h. 25′, The ſame two belts; a ſtrong, dark ſpot, near the margin of the diſk; ſee fig. 9.; ring not expreſſed.

10 h. 1′, The ſpot not ſo remarkable as it was at 9 h. 25′.

— 26, Small twenty-feet teleſcope; an equatorial belt, and another leſs marked.

— 29, Two dark equatorial belts.

April 19, Two belts.

Auguſt 23, Two belts, a little declining from the equatorial poſition.

Auguſt 26, A broad belt much inclined; with 200, 250, 300, 400, faint appearances of a ſecond and of a third belt.

—— 27, The belts leſs inclined.

Sept. 2, A darkiſh belt, but very little inclined; and a fine white belt, cloſe to the ring.

— 5, The belt a little inclined.

— 6, The belt not inclined.

— 8, The bright belt cloſe to the ring, and two dark equatorial belts.

It will not be neceſſary to continue the account of theſe belts up to the preſent time; but I have conſtantly obſerved them, and found them generally in equatorial ſituations, though now and then they were otherwiſe.

We may draw two concluſions from what has been reported. The firſt, which relates to the changes in the appearance of the belts, is, that Saturn has probably a very conſiderable atmoſphere, in which theſe changes take place; juſt as the alterations in the belts of Jupiter have been ſhewn, with great probability, to be in his atmoſphere. This has alſo been confirmed by other obſervations: thus, in occultations of Saturn's ſatellites, I have found them to hang to the diſk a long while before they would vaniſh. And though we ought to make ſome allowance for the encroachment of light, whereby a ſatellite is ſeen to reach up to the diſk ſooner than it actually does, yet, without a conſiderable refraction, it could hardly be kept ſo long in view after the apparent contact. The time of hanging upon the diſk, in the ſeventh ſatellite, has actually amounted to 20 minutes. Now, as its quick motion during that interval carries it through an arch of near ſix degrees, we find, that this would denote a refraction of about two ſeconds, provided the encroaching of light had no ſhare in the effect. By an obſervation of the ſixth ſatellite, the refraction of Saturn's atmoſphere amounts to nearly the ſame quantity; for this ſatellite remained about 14 or 15 minutes longer in view than it ſhould have done; and as it moves about 2¾ degrees in that time, and its orbit is larger than that of the ſeventh, the difference is inconſiderable. It is not my preſent intention to enter into a conſideration of the amount of theſe refractions, otherwiſe we might perhaps find data enough to ſubject them to ſome calculation. But what has been ſaid will ſuffice to ſhew, that very probably Saturn has an atmoſphere of a conſiderable denſity.

The next inference we may draw from the appearance of the belts on Saturn is, that this planet turns upon an axis which is perpendicular to the ring. The arrangement of the belts, during the courſe of fourteen years that I have obſerved them, has always followed the direction of the ring, which is what I have called being equatorial. Thus, as the ring opened, the belts began to advance towards the ſouth; and to ſhew an incurvature anſwering to the projection of an equatorial line, or to a parallel of the ſame. When the ring cloſed up, they returned towards the north; and are now, while the ring paſſes over the center, exactly ranging with the ſhadow of it on the body; generally one on each ſide, with a white belt cloſe to it. When I ſay, that the belts have always been equatorial, I paſs over trifling exceptions, which certainly were owing to local cauſes. The ſtep from equatorial belts to a rotation on an axis is ſo eaſy, and, in the caſe of Jupiter, ſo well aſcertained, that I ſhall not heſitate to take the ſame conſequence for granted here. But, if there could remain a doubt, the obſervations of

June 19, 20, and 21, 1780, where the ſame ſpot was ſeen in three different ſituations, would remove it completely.

There is another argument, of equal validity with the former, which now I ſhall bring on. It is founded upon the following obſervations, and will ſhew that Saturn, like Jupiter, Mars, and the Earth, is flattened at the Poles; and therefore ought to be ſuppoſed to turn on its axis.

July 22, 1776. I thought Saturn was not exactly round.

May 31, 1781. It appears as if the body of Saturn was at leaſt as much flattened as that of Jupiter; but as the ring interferes, this may be better aſcertained eight years hence.

Auguſt 18, 1787. The body of Saturn is of unequal diameters, the equatorial one being the longeſt.

Sept. 14, 1789, 23 h. 36′ 32″. Having reſerved the examination of the two diameters of Saturn to the preſent as the moſt favourable time, I meaſured them with my twenty-feet reflector, and a good parallel-wire micrometer.

		″
Equatorial diameter,	1ſt meaſure,	21,94
	2d . . .	23,11
	3d . . .	21,73
	4th . .	22,85
	Mean	22,81
Polar diameter,	1ſt meaſure,	20,57
	2d . . .	20,10
	3d . . .	21,16
	Mean	20,61

By this it appears that Saturn is conſiderably flattened at the poles. And as the greateſt meaſures were taken in the line of the ring and of the belts, we are aſſured that the axis of the planet is perpendicular to the plane of the ring; and that the equatorial diameter is to the polar one nearly as 11 to 10.

We may alſo infer the real diameter of Saturn from theſe meaſures, which are perhaps more to be depended upon than any that have hitherto been given. But as in my journal I have meaſures that were repeatedly taken theſe ten years paſt, not only of the diameter of Saturn, but of the ring, and its opening, whereby its inclination may be known; as well as of the diſtance of the fourth, and fifth, and other ſatellites, which will be of great uſe in aſcertaining the quantity of matter contained in the planet, I reſerve a full inveſtigation of theſe things for another opportunity; ſince, from the date of this Paper, it will be ſufficiently evident, that there can be no time for me to enter properly into the ſubject.

One beautiful obſervation of the tranſit of the ſhadow of the fourth ſatellite over the diſk of Saturn, I muſt add, to conclude this Paper.

Laſt night, November 2, 1789, at 23 h. 13′ ſidereal time, being always in queſt of any appearance that may afford the means of aſcertaining the rotation of Saturn on an axis, I diſcovered a black ſpot on the following margin of the diſk of that planet.

At 23 h. 21′, I perceived a protuberance on the ſouth preceding edge of the diſk, which I ſuppoſed to be the fourth ſatellite going to emerge.

At 23′, I found that the black ſpot had advanced a little towards the preceding ſide.

At 30′, with a power of 300, I found it ſtill advancing, and ſaw that the ſpot was a little to the north of the equatorial belt, but ſo that a ſmall part of it was upon the belt.

At 35′, the black ſpot was a little more than one-eighth of the diameter of Saturn advanced from the following edge towards the center.

At 39′, the ſatellite was detached.

At 49′, the ſpot was advanced ſo as to be about one-third of its way towards the center; and the fourth ſatellite near half its own apparent diameter clear of the edge.

In this ſituation of the planet I took an eye-draught of it, (ſee fig. 10.) as it appeared with the black ſpot on the belt; the lately emerged fourth ſatellite; two parallel dark belts, the intermediate ſpace between them and the equatorial one being a little brighter than the reſt of the diſk; the ſixth, third, and ſecond ſatellites on the preceding ſide; the ring projecting like two very ſlender lines on each ſide of the diſk, and containing the firſt ſatellite upon the following arm, with the fifth at a conſiderable diſtance following.

At 0 h. 5′, the black ſpot was got a little more than half way towards the center. It was much darker than the belt, and more upon it than before.

At 1 h. 2′, by advancing gradually towards the ſouth, it was now almoſt intirely drawn upon the equatorial belt.

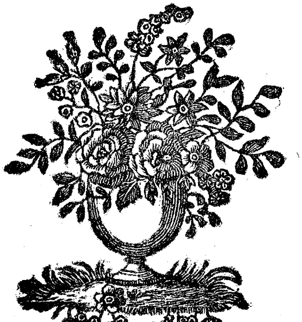
At 1 h. 13′, the black ſpot approached towards a central ſituation.

At 1 h. 21′ 51″, it was perfectly central, and at the ſame time upon the middle of the equatorial belt.

I followed the ſhadow of the ſatellite with great attention up to the center, in order to ſecure a valuable epocha, which may ſerve to improve our tables of the mean motion of this ſatellite.

WILLIAM HERSCHEL.

Slough, near Windſor,
November 3, 1789.



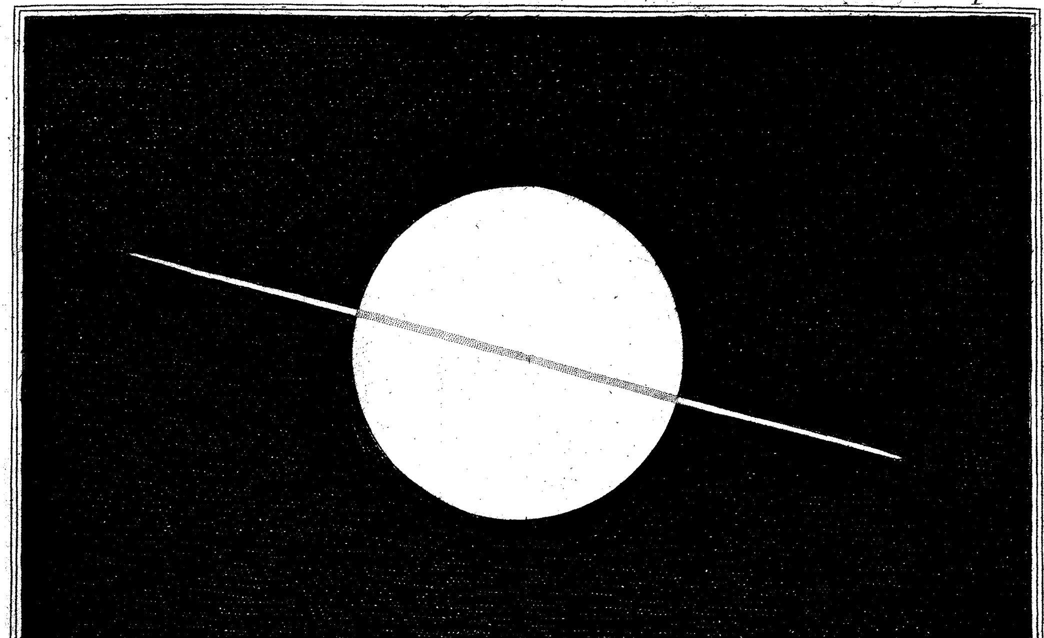


Fig. 1.

March 17. 1774.

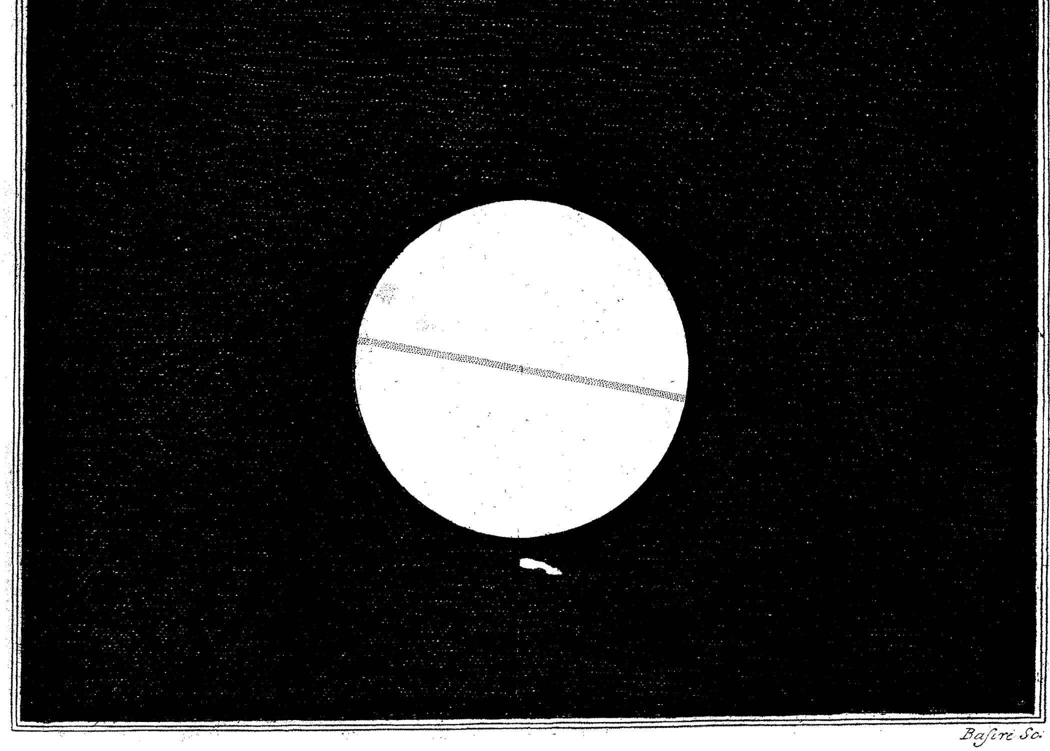


Fig. 2.

April 3. 1774.

Basire Sc.

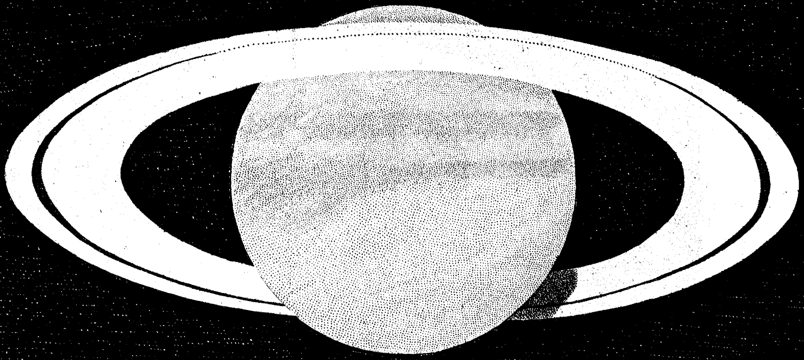


Fig. 3.

June 20th 1778.

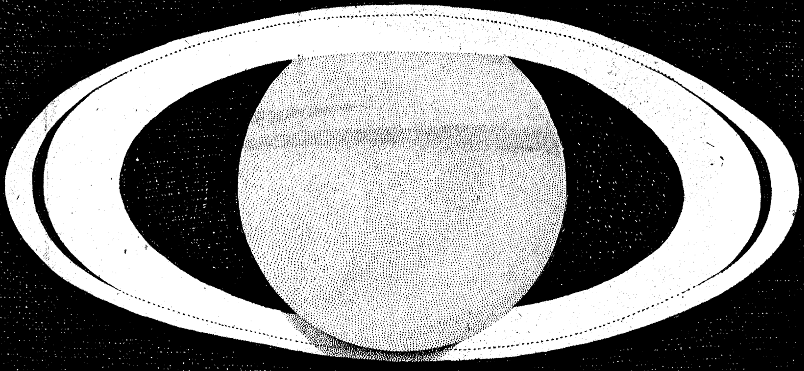


Fig. 4.

May 11th 1780.

Basire Sc.

Fig. 5.

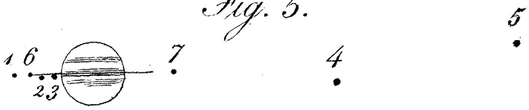


Fig. 6.

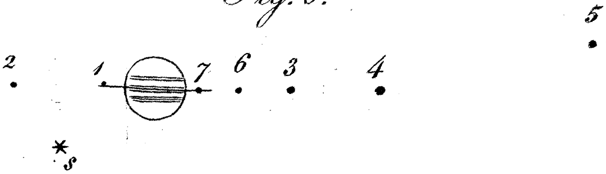


Fig. 7.

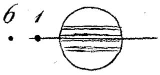


Fig. 8.

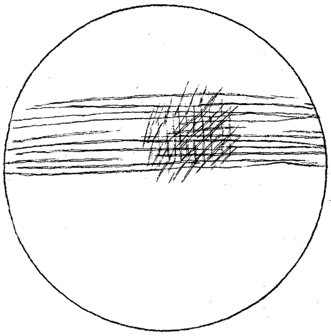


Fig. 9.

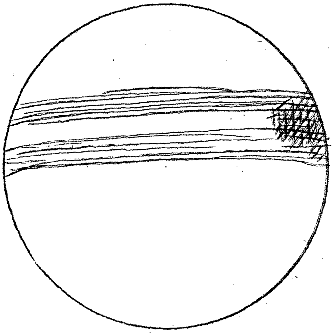
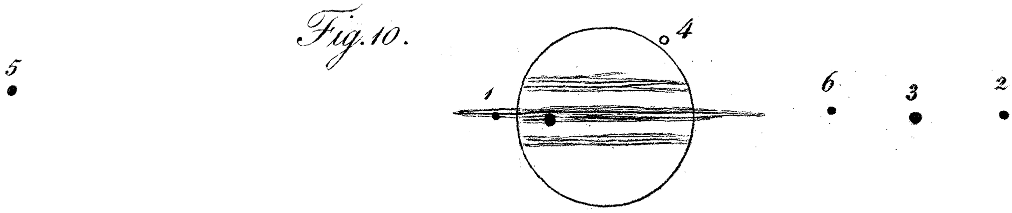


Fig. 10.



Basire Sc.